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Search for resonant WZ Production with the ATLAS detector at the LHC

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Resonance searches are well motivated

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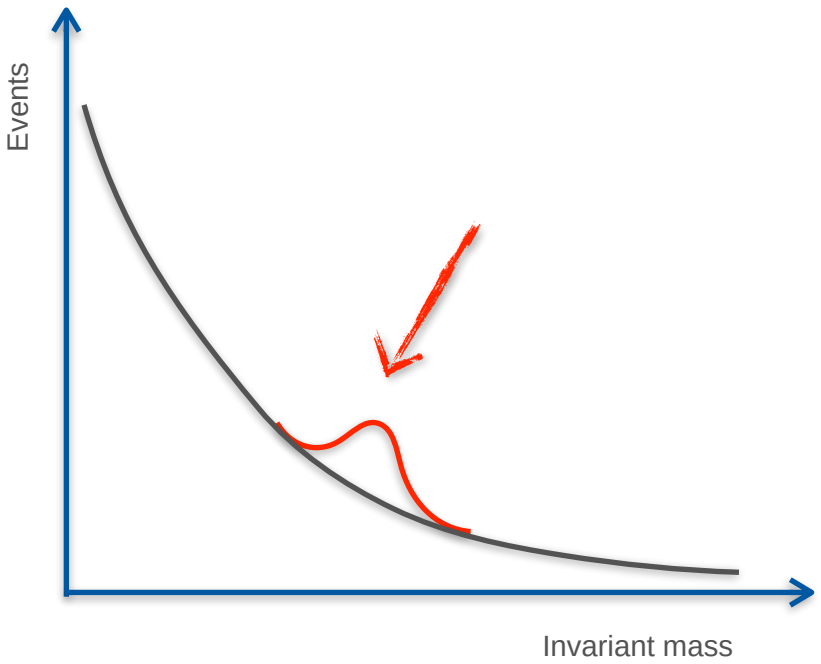
- Resonances represent the simplest way to discover new particles
- A statistically significant bump above a smooth background
  - experimentally robust
  - small systematics
  - difficult for unknown backgrounds to mimic
- Model-independent probe to new physics
- Predicted in many beyond SM scenarios with different properties (charge, spin, width, production mechanism)



High mass diboson searches are well motivated

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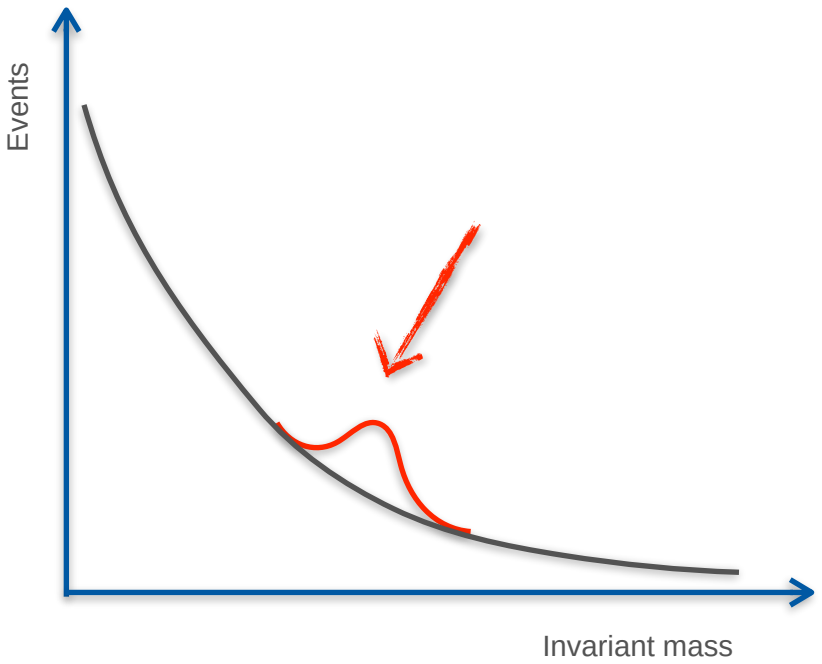
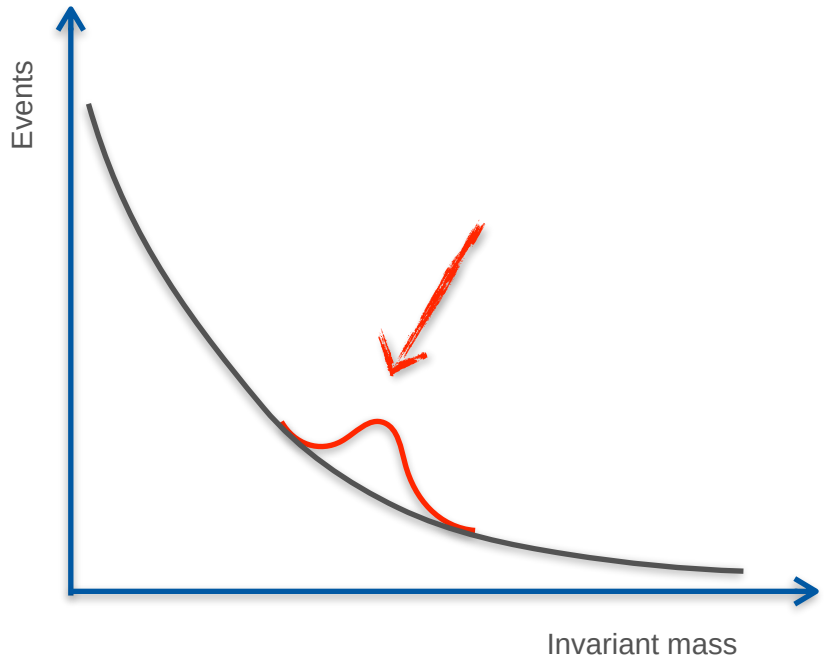


- Resonance benchmarks you will hear about in this talk
  - Heavy Vector Triplets or **HVT** (simplified Lagrangian) : Model A (g_V=1) and Model B (g_V=3)
  - Georgi-Machacek (GM) Higgs Triplet Model : H^+_5
  - Extended gauge model (EGM) : with a spin-1 W′ boson

Search strategy

- Choose a WZ decay mode
- Design a selection
- Estimate the background
- Reconstruct invariant mass
- Set limits on BSM theories



WZ decay modes

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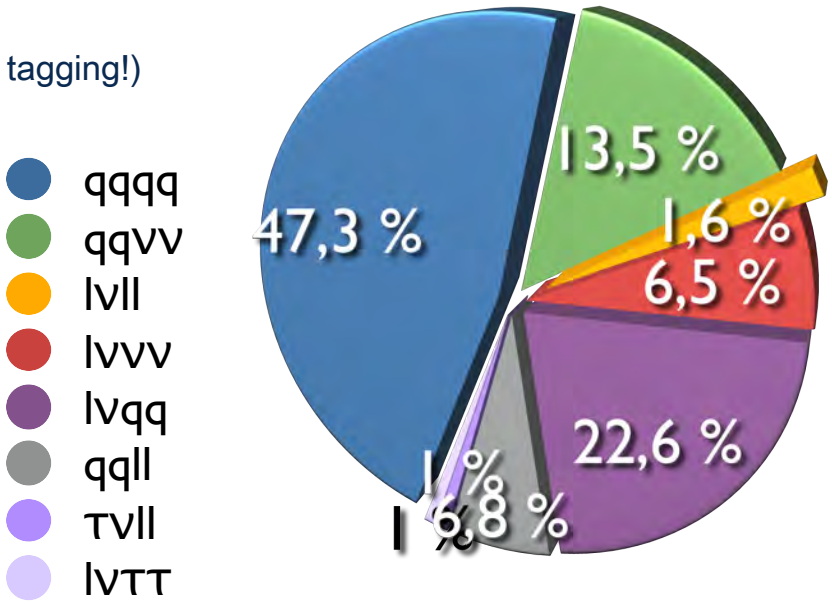
Hadronic decays:

- Larger branching fractions
- More backgrounds from QCD/multijet events (→ boson tagging!)

Leptonic decays:

- Small branching fractions
- Clean signature, low background



Fully leptonic decay

Experimental signature:

- 3 high p_T, isolated leptons,
- Missing transverse energy (E_T^{miss})

Backgrounds:

- Non resonant WZ
- Z+jets, Top, Z+γ, ZZ, and VVV

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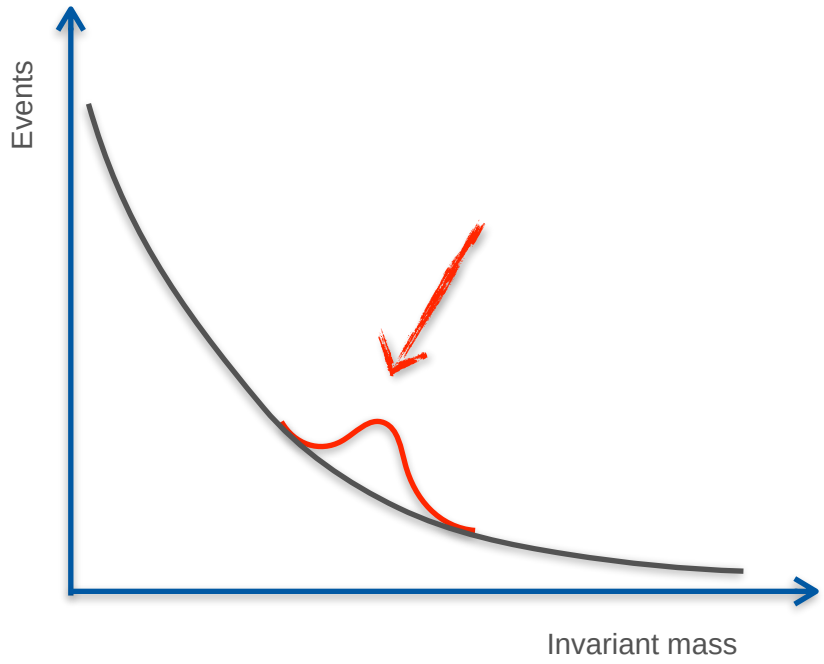

WZ object and event selection

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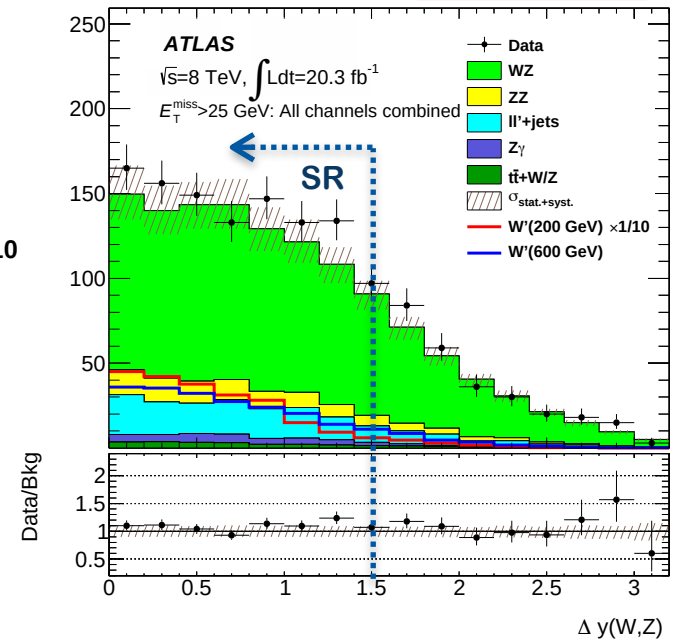
		Motivation :
lepton selection	Single lepton trigger	High efficiency 3 leptons in final state
	High p_T leptons (p_T>25 GeV) in detector acceptance	
	Leptons must come from primary vertex. Impact parameter cuts $\|d0/\sigma_{d0}\|$	reduce background from jet, Z+jet, QCD, tt and single top
	Calorimeter and track isolation used	
	Only 3 good leptons (additional 20 GeV leptons)	Reduce ZZ background
Z selection	Pair of same flavor, opposite sign , high p_T isolated leptons. Consistent with a Z boson in a ±20 GeV window. If more than one pair, select the closest to Z mass	reduce non peaking backgrounds like tt and single top, WW+jets
W selection	Additional tight lepton requirement	reduce the Z+jets and Top background
	E_T^{miss}>25GeV	To account for the W and reduce Z+jets

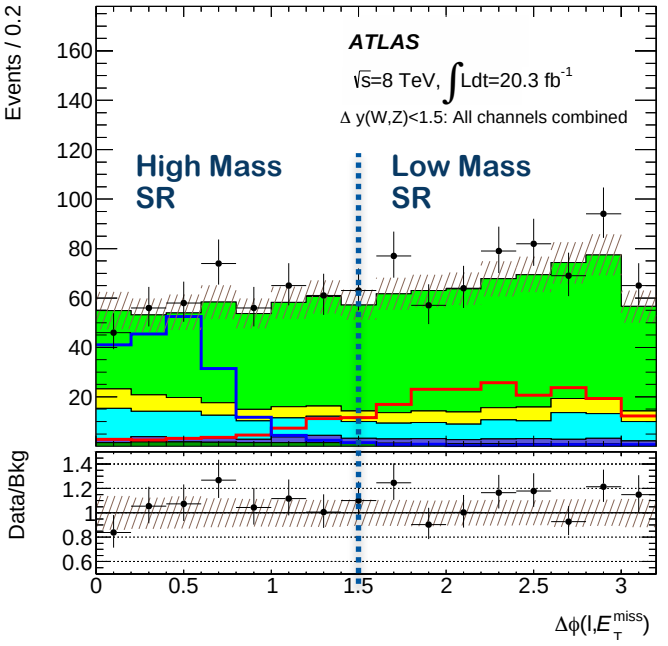
Signal optimization

- Improve the sensitivity to resonant signals some additional selections can be added, for example:
  - $\Delta y(W, Z) < 1.5 \rightarrow$ remove SM background
  - $\Delta\varphi(\ell, E_T^{miss})$ is used to define 2 signal regions (SR)
    - Low Mass SR : $\Delta\varphi(\ell, E_T^{miss})<1.5$
    - High Mass SR : $\Delta\varphi(\ell, E_T^{miss})>1.5$

ATLAS 8 TeV

arXiv:1406.4456





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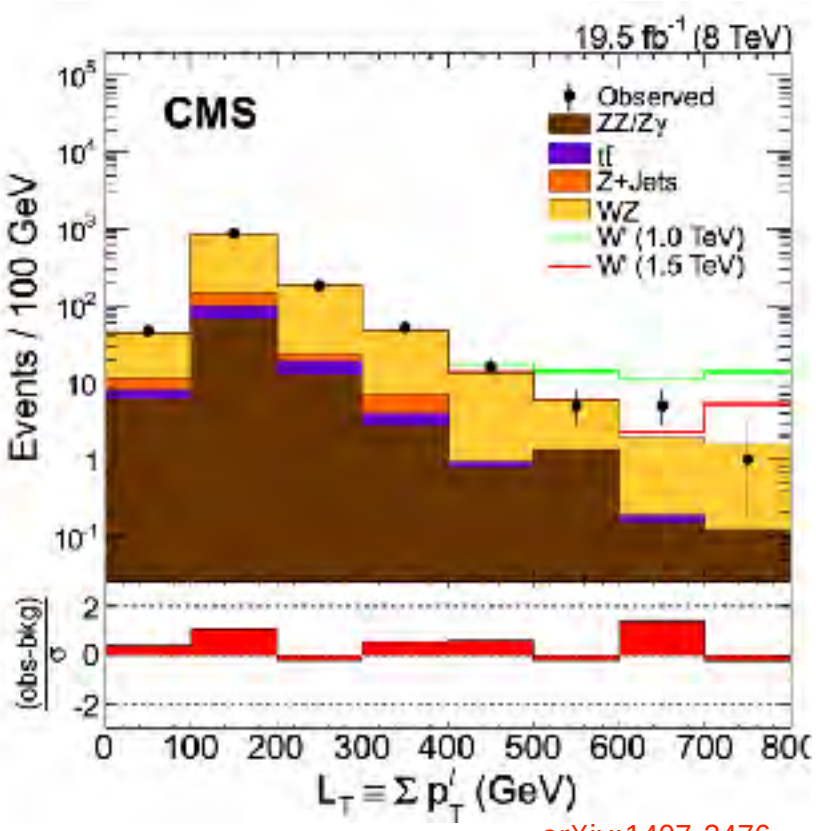
CMS 8 TeV

- L_T the scalar sum of the leptons p_T cut value changing depending on m_{WZ}



arXiv:1407.3476

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CMS 8 TeV

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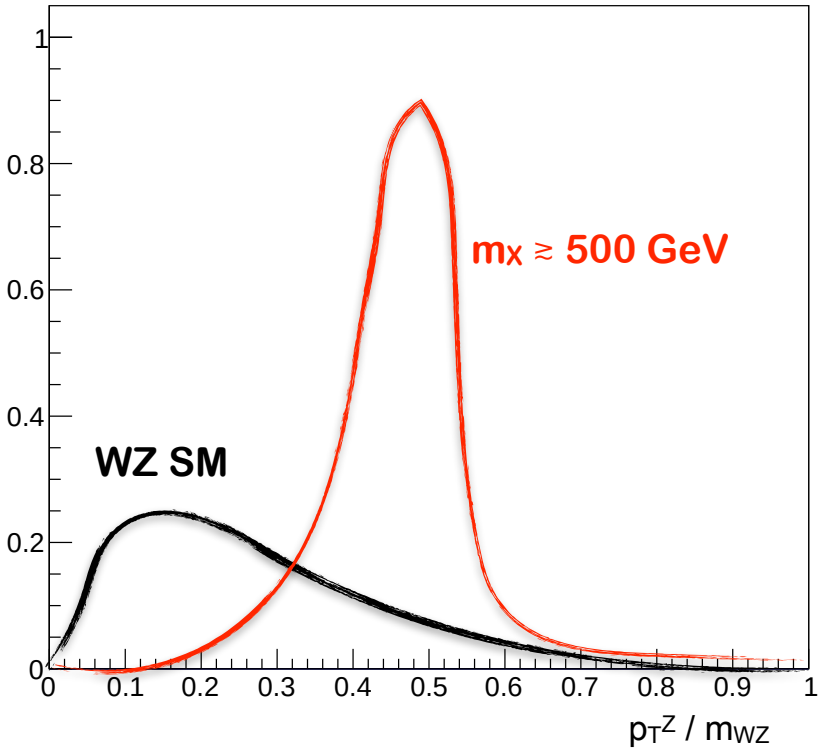
Other

- The ratio between the boson p_T and the m_{WZ} mass
  - p_T^W / m_{WZ} and p_T^Z / m_{WZ}



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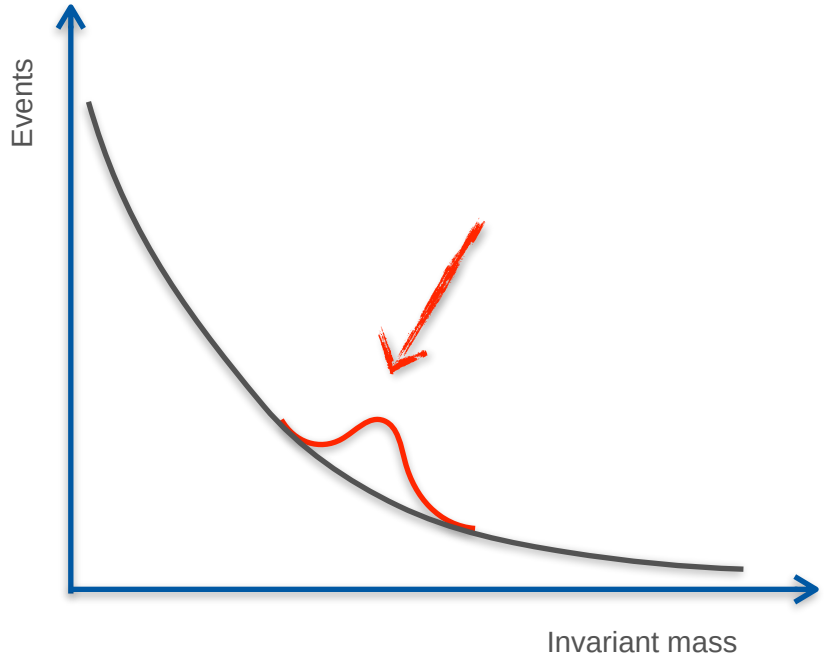
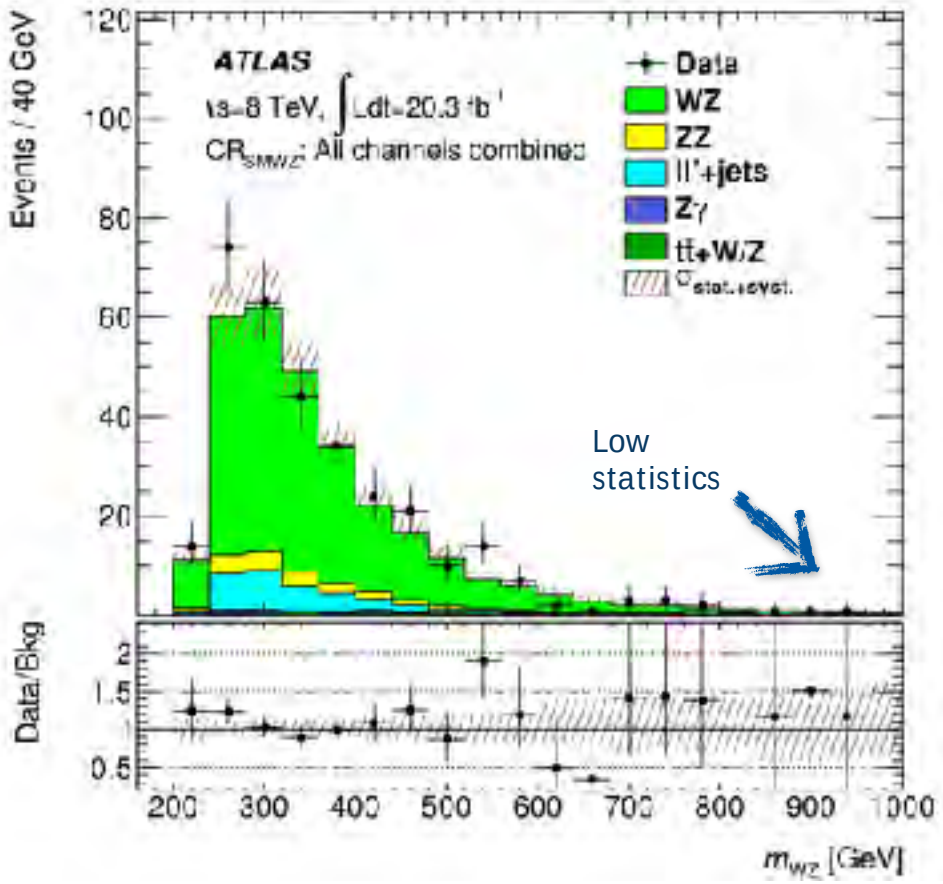


Background estimation

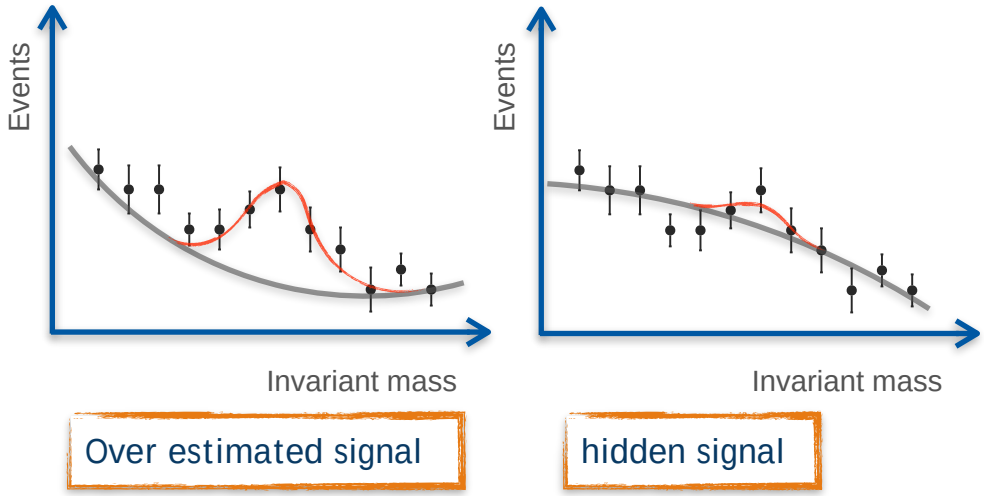
- Accurate background estimate to not bias signal extraction
- Two techniques
  - background shape from simulation and normalize in control region + theory/ experimental systematic
    - ex. ATLAS WZ control region :
      - $\Delta y(W, Z)$ requirement reversed → reduce signal contamination
      - $\Delta\varphi(\ell, E_T^{miss})$ is removed

arXiv:1406.4456



Background estimation

- Accurate background estimate to not bias signal extraction
- Two techniques
  - background shape from simulation and normalize in control region + theory/ experimental systematic
  - parameterize the background shape and fit directly on data
    - ex. ATLAS 8 TeV to estimate the background at high mass analysis 2 fits were performed
      1. WZ bkg with m_{WZ} > 500 GeV
      2. non-WZ bkg with m_{WZ} > 300 GeV
    - The power-law function $N(x) = c_0 x^{c_1}$, where x is m_{WZ}



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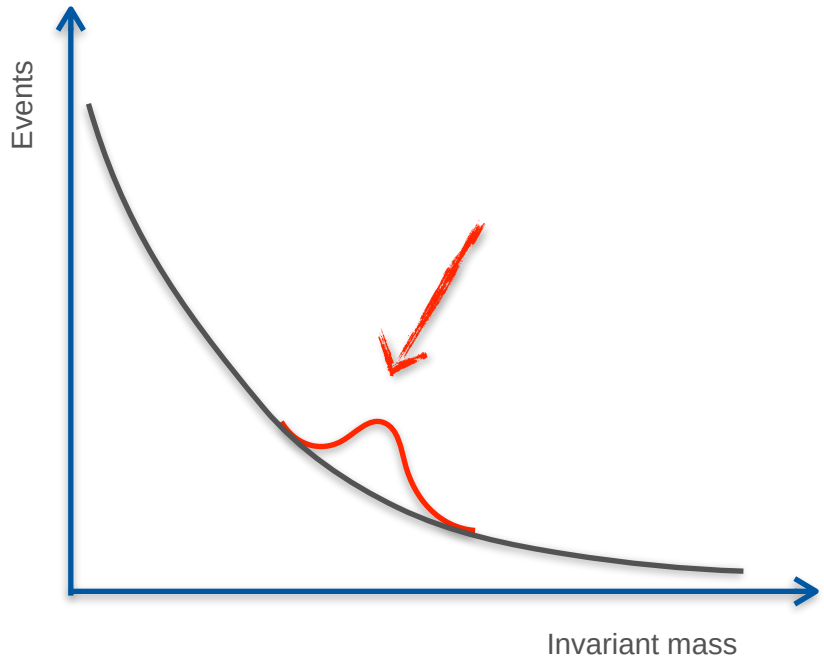
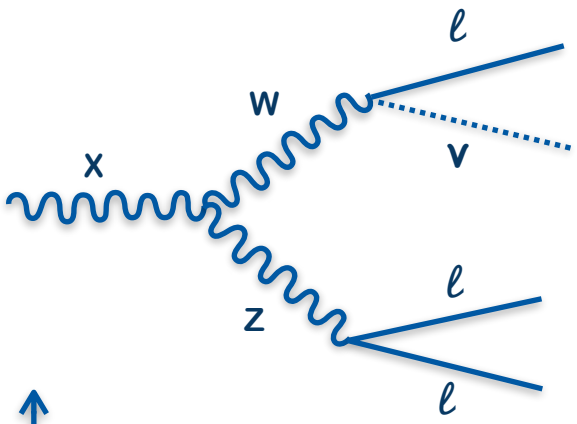
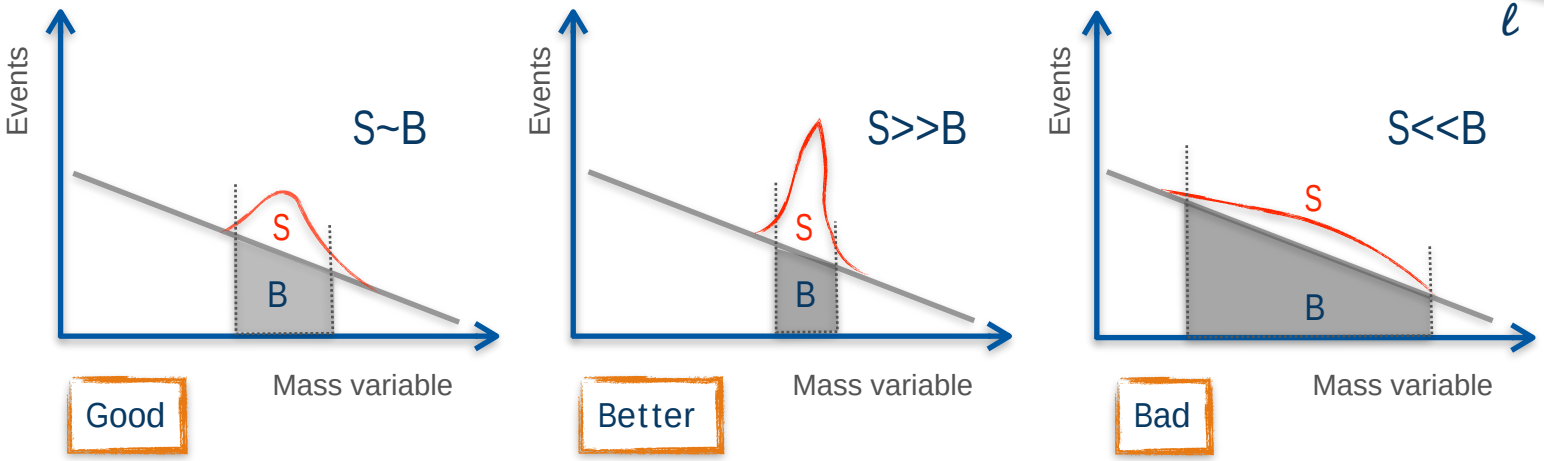


Mass reconstruction

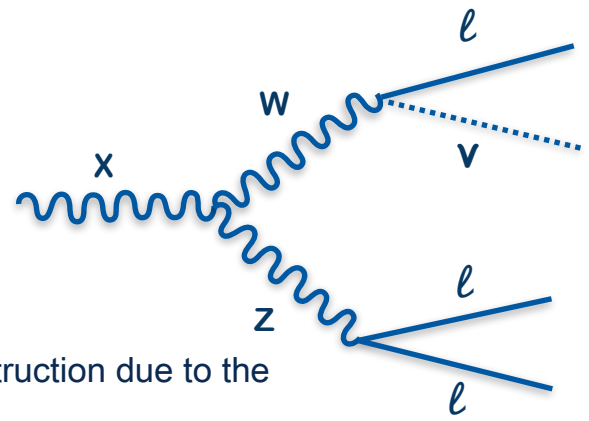


- Mass reconstruction and resolution crucial in resonance searches
  - statistical power inversely proportional to the mass resolution
  - resonance hidden by bad understanding of resolution



- Need ad-hoc studies and calibration strategies at such large momenta

Mass reconstruction



- Mass reconstruction and resolution crucial in resonance searches
  - statistical power inversely proportional to the mass resolution
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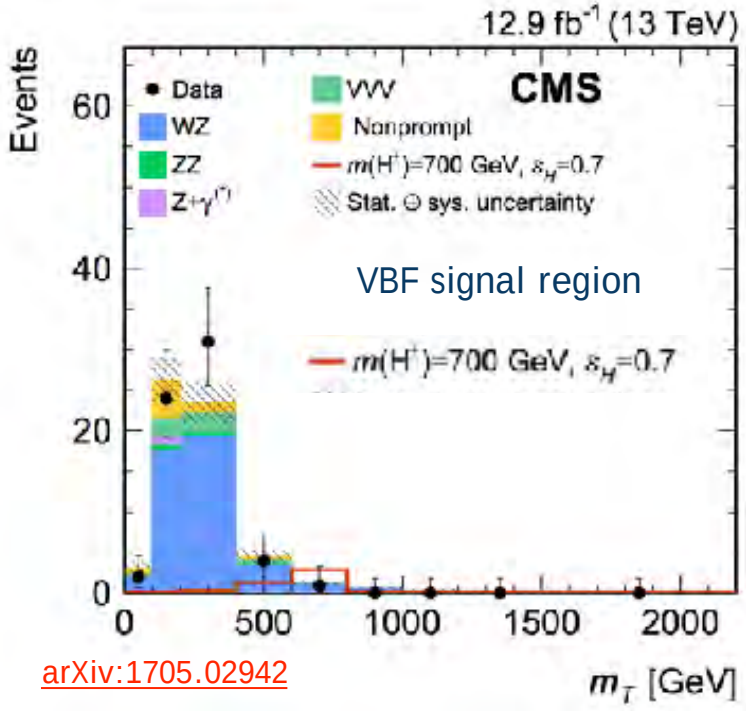
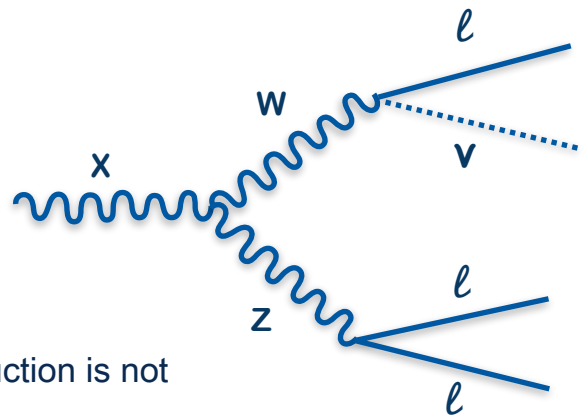
- In the $X \rightarrow WZ \rightarrow \ell\nu\ell\ell$ channel the incomplete invariant mass reconstruction due to the missing neutrino the p_Z information
  - Use the $\ell\nu\ell\ell$ transverse mass information
    - ex. CMS result at 13 TeV for the H^+_5



arXiv:1705.02942

Mass reconstruction



- Mass reconstruction and resolution crucial in resonance searches
  - statistical power inversely proportional to the mass resolution
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- In the $X \rightarrow WZ \rightarrow \ell\nu\ell\ell$ channel the complete invariant mass reconstruction is not possible due to the missing neutrino the p_Z information
  - Use the $\ell\nu\ell\ell$ transverse mass information
  - Assume a W on-shell and solve the equation to obtain the neutrino p_Z information
    - several solutions are posible → optimization based on resolution (~10% at 1 TeV)

8 TeV Results

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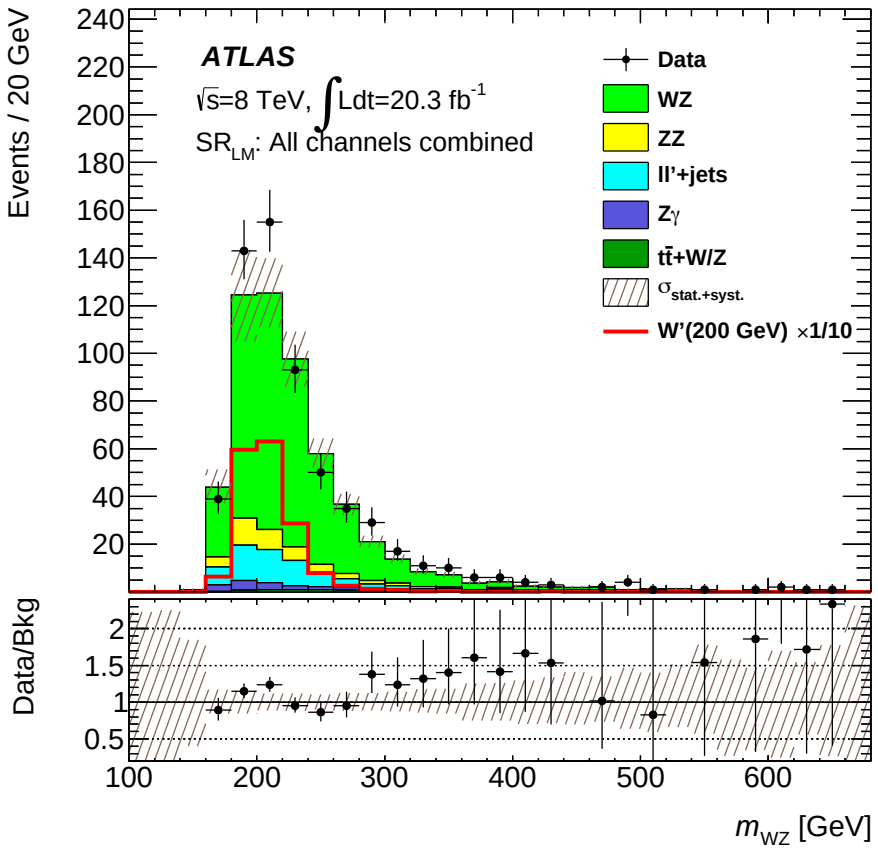
arXiv:1406.4456

Low Mass signal region



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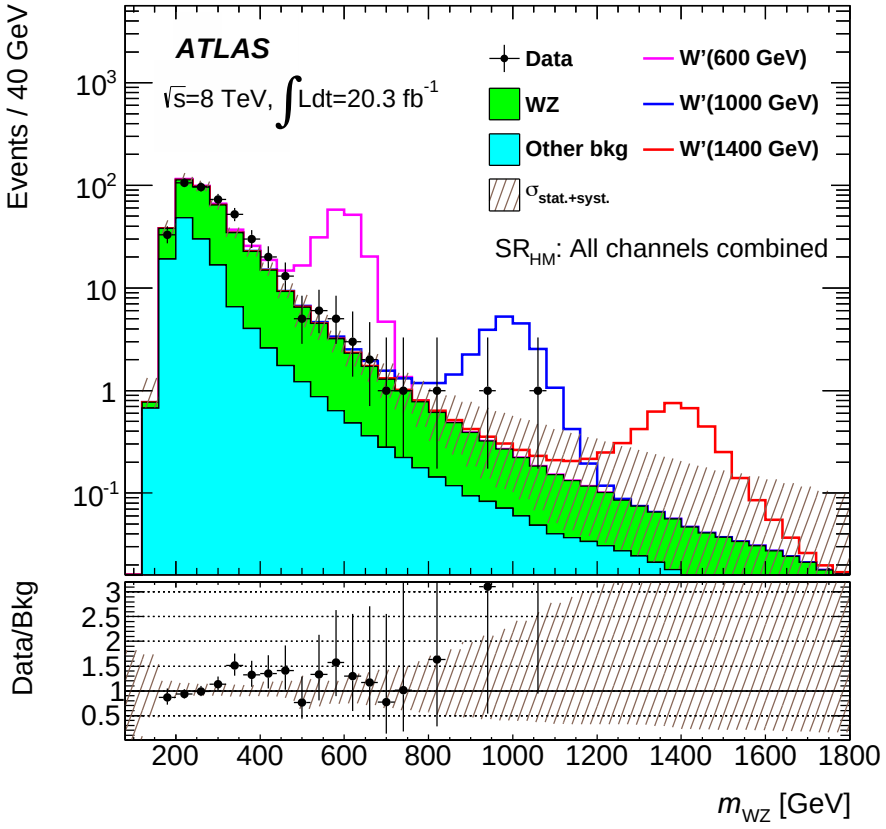

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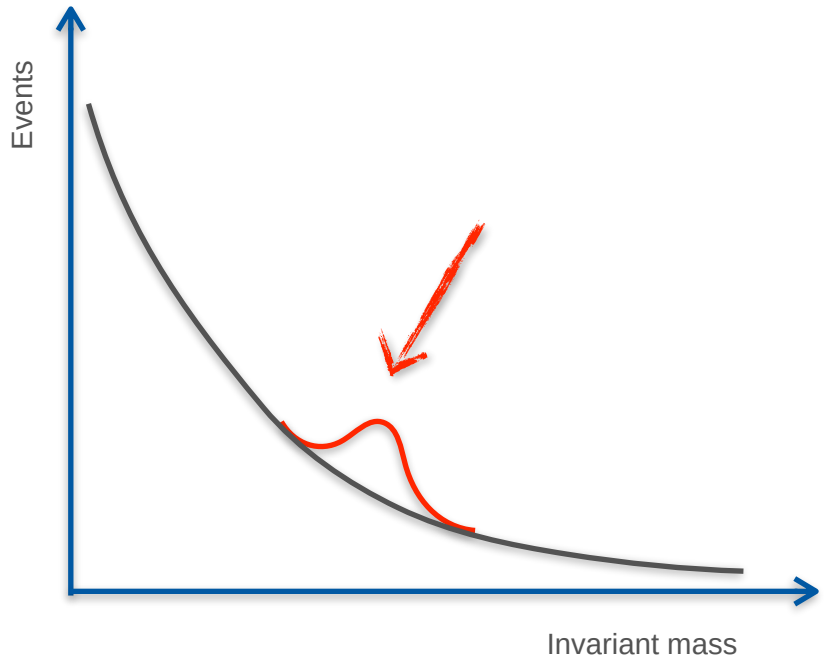

Limits on BSM theories

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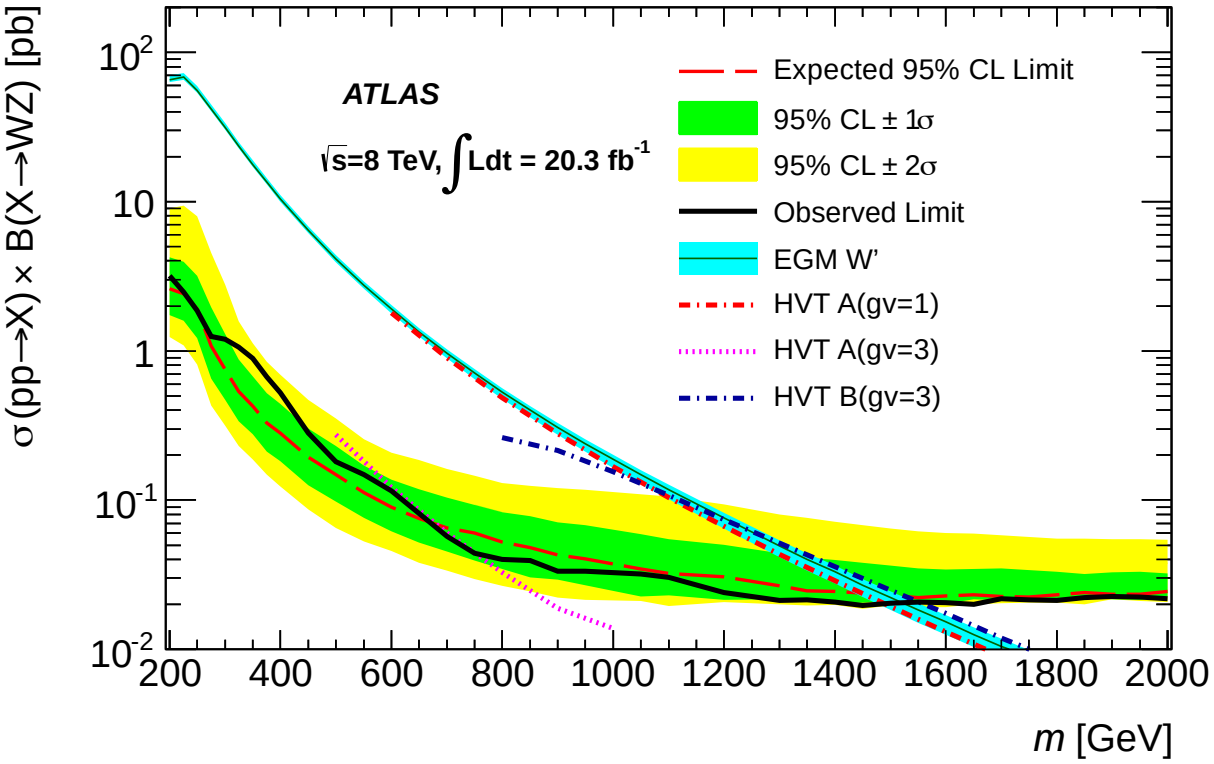
arXiv:1406.4456

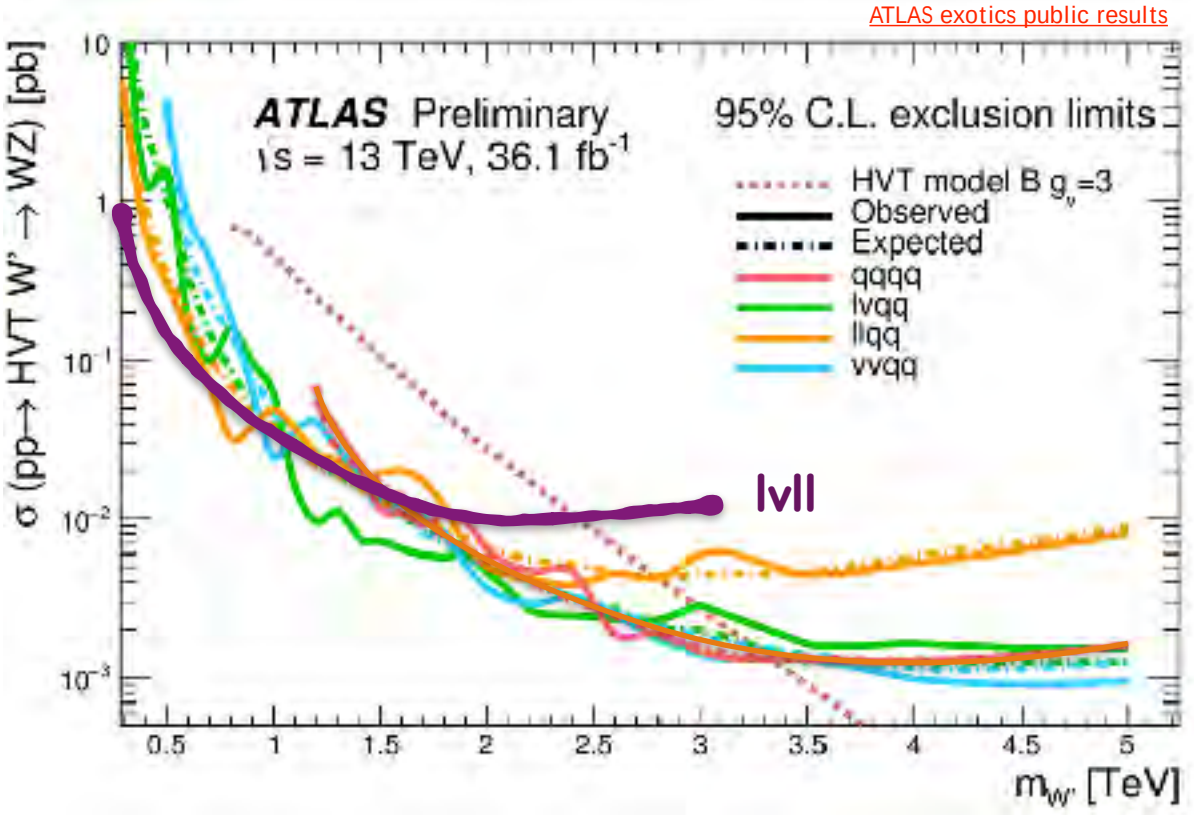
- Limits are extracted by using a binned Fit of the WZ invariant mass shape
  - All lepton decay are combined
  - The systematics uncertainties are included in the fit being the SM WZ background the dominant one
- For m < 400 GeV, the two SR are combined to maximize the sensitivity of the search. For m > 400 GeV, only the High Mass SR is used.



- A mass limit of 1.52 TeV is derived for the W'

The 13 TeV big picture

ATLAS exotics public results



lvll, llqq

- Low mass region → good resolution
- High mass region → statistically limited

lvqq

- Good sensitivity in wide mass region

vvqq:

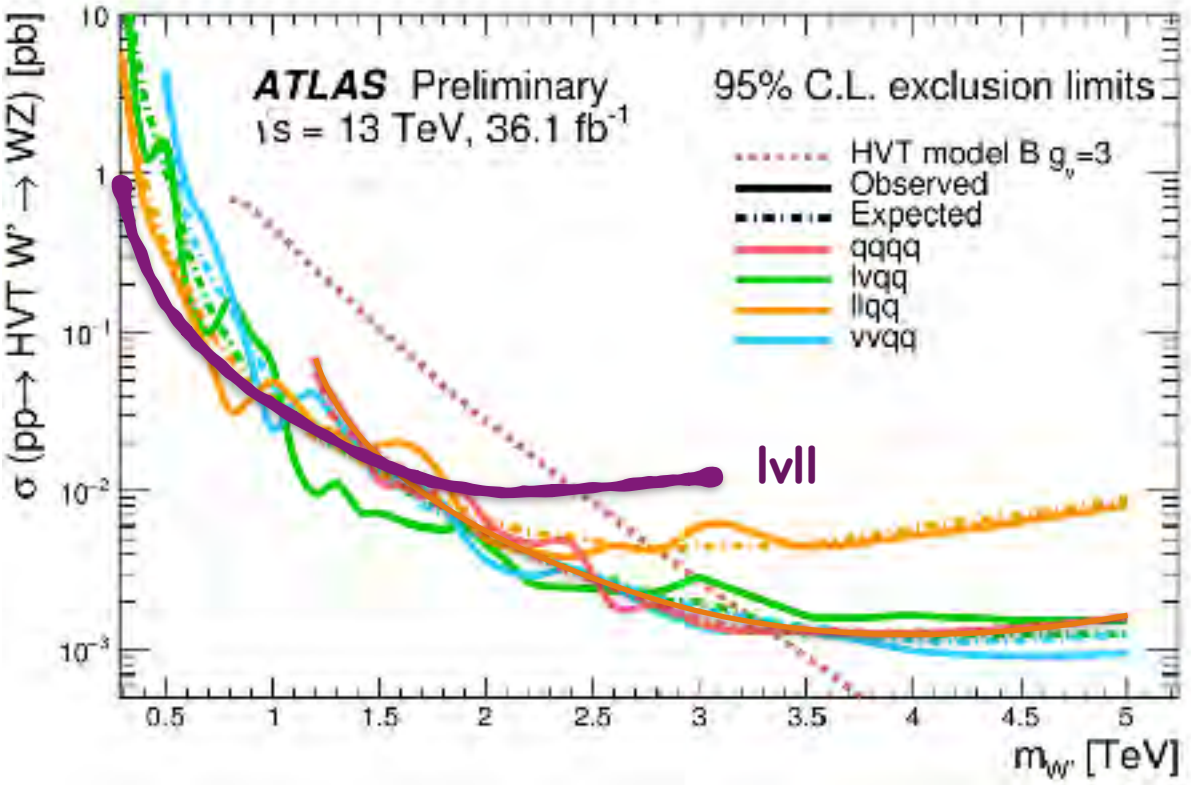
- Low mass region → bad mass resolution
- High mass region → high statistics

qqqq:

- Low mass → QCD background
- High mass → Jet related uncertainties

Summary

- Search for heavy resonances in the dibosons channels is one of the most direct ways to find new physics
- New results and more Run-2 data are coming! Stay tune…



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Backup